THE WORKING GROUP ON GLOBAL NAVIGATION SATELLITE SYSTEMS

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MANDATE

On the basis of the fourth and fifth Workshop findings and subsequent developments, examine further the role of private- and public-sector international cooperation and competition in current and future global navigation satellite systems (GNSS).

EXECUTIVE SUMMARY

Building on the efforts of the two previous Workshops on GNSS, this year's Working Group addressed critical near-term and emerging issues primarily associated with the development of next-generation GNSS architectures, with a focus on maximizing user benefits. Issues addressed include interoperability, institutional models for cooperation, integrity provision (a new topic since the 1999 Bermuda Workshop), spectrum protection, safety and security, liability, and user support within developing nations. Some of the recommendations require urgent action, especially when they address issues that might affect next-generation systems that are currently being defined, and others call for longer-term or continuous action (e.g., spectrum protection, liability, user support within developing nations).

One of the most pressing needs in the development of next-generation GNSS is for greater understanding of how these systems will operate and complement each other to maximize their benefits for all users. As the next-generation systems are currently being defined, decisions will need to be made very soon if the greatest benefits to end users are to be achieved. The kind of understanding needed between system developers can only be achieved through open and continuous communication among the government and industry players, which unfortunately, has been hampered by the slow pace of formal consultations between the United States and the European Union. The first recommendation is a call for action on the part of the European Union, United States, and Russia to develop a common view on system interoperability in a time frame that fits with the program development schedules for Europe's Galileo system, the U.S. Global Positioning System (GPS) and Russia's Global Navigation Satellite System (GLONASS).

Another area that will impact next-generation systems, and a new topic at this year's Workshop, is the provision of integrity services that measure the usability of GNSS signals. Current approaches to providing the different levels of integrity required for the various transportation modes include both regional and local augmentation systems. Next-generation GNSS architecture studies are assessing more efficient and less infrastructure-intensive approaches to providing integrity services on a global basis. The recommendation in this area calls for international transportation standards organizations to develop a common understanding of global integrity needs and to investigate the feasibility and desirability of common global integrity standards.

A number of specific recommendations are made regarding the responsibilities incumbent on GNSS user nations and the continuing need for protection of GNSS spectrum from interference and reallocation. Two recommendations are targeted at the upcoming series of GNSS workshops being sponsored by the U.N. Office of Outer Space Affairs in response to recommendations from the 1999 Bermuda Workshop. As part of this effort to inform developing nations about GNSS applications and benefits, the workshops should include discussions of the need for developing nations to support protection of GNSS spectrum and the responsibilities they have for ensuring appropriate levels of GNSS service and optimum benefits for their users. A new issue that has arisen since the Bermuda Workshop is the potential interference to GNSS from proposed ultrawideband (UWB) systems. Recent studies and tests have shown that these systems can interfere with the low-power GNSS signals, and focused steps must be taken to protect GNSS spectrum from UWB interference.

Additional recommendations were made in the areas of safety and security, liability, and institutional models for cooperation, and these are detailed in the body of the report.

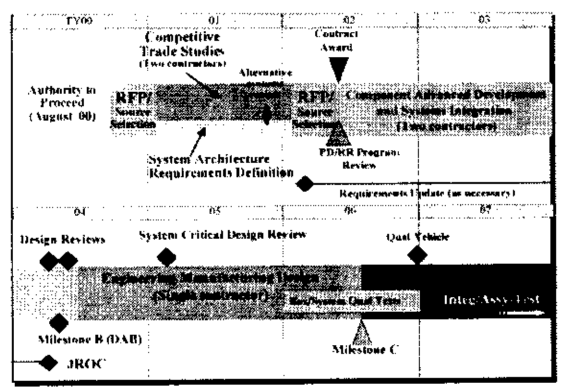
Background

GNSS was first addressed at the Fourth AIAA International Space Cooperation Workshop in Banff in January 1998. Findings from the first Workshop favored either one GNSS, or global interoperability of separate systems, as opposed to competing national or regional systems. The current GNSS architecture comprises the United States GPS and the Russian GLONASS core systems, along with satellite- and ground-based augmentations that have either been deployed or are under development in the United States, Europe, Japan, and elsewhere to improve the accuracy, integrity, and availability of the basic GPS and GLONASS civil services.

The focus of the Fifth Workshop in Bermuda in April 1999 was on issues related to the proposed European Galileo system and the potential for truly "seamless" global interoperability between independent satellite navigation systems. Recommendations aimed at ensuring interoperability included the establishment of common definitions for open systems architecture and basic civil and public safety GNSS services; a common approach to spectrum protection within the GNSS community prior to the 2000 World Radio Conference (WRC); the resolution of differing U.S. and E.U. views regarding the need for a new GNSS liability regime; and an increased emphasis on security issues during ongoing E.U.–U.S. and Japan–U.S. consultations on GNSS cooperation.

A number of important developments in the current and future GNSS elements have occurred since the conclusion of the Bermuda Workshop. Since April 1999, U.S. plans for modernizing GPS have evolved in several ways. First, a decision was made in the fall of 1999 to accelerate the introduction of a new military signal structure and a second coded civil signal by modifying many of the already built GPS Block IIR satellites. Later, the program was again restructured by reducing the number of Block IIF satellites to be procured to only 12. In conjunction with this decision, a new development program was initiated, known as GPS III, to reassess the entire GPS architecture in an effort to address all dual-use positioning, navigation, and timing requirements for the long term in a cost-effective manner. A simplified schedule for the GPS III effort is shown in Figure 1. Perhaps the most dramatic GPS development since the Bermuda Workshop occurred on 1 May 2000, when GPS Selective Availability (SA, the technique employed to degrade the quality and accuracy of GPS civil signals) was discontinued a full six years ahead of schedule. (U.S. GPS policy, established by Presidential Decision Directive in 1996, called for SA to be discontinued within 10 years.) This action resulted in immediate and significant benefits to GPS users worldwide when observed position accuracy improved to approximately 10 meters.

Figure 1: The Current GPS III Program Schedule

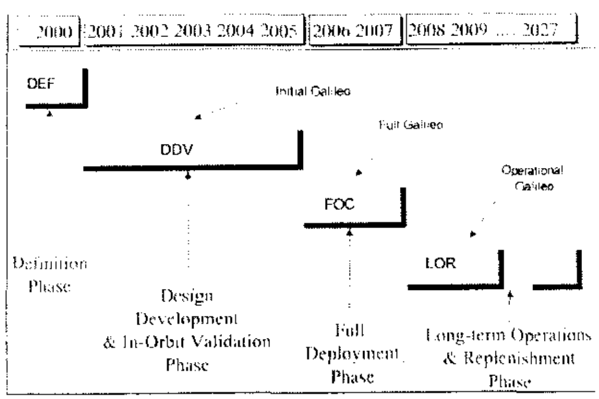


The GPS program has also been evolving toward a greater civil role in policy decisions and management structures. This is being accomplished through the inclusion of U.S. federal civil agency participation in the Department of Defense GPS requirements development and acquisition processes.

There have also been a number of important developments in Europe's Galileo program since the last Workshop. Galileo has been proceeding through its definition phase, which initiated eight major studies focused on architecture definition, satellite and control segment design, service definitions, and other issues such as the appropriate integration of the European Geosynchronous Navigation Overlay Service (EGNOS), a satellite-based GNSS augmentation system for transportation users, into Galileo. Stressing both European independence and potential interoperability with other elements of GNSS, the baseline Galileo design currently consists of 30 medium Earth orbit (MEO) satellites providing three levels of navigation service using four L-band carrier frequencies. Global broadcast of GNSS integrity and a search and rescue payload are also part of the baseline architecture.

Institutionally, a Galileo Steering Committee and a Navigation Programme Board are in place to interface with E.U. and ESA member states. A Program Management Board and Program Office have also been established by the European Commission and ESA for the joint management of the program. Although a decision to proceed with the development of Galileo was not forthcoming in December 2000 as had been desired, initial activities for the next phase of the program have already been launched. Assuming a positive decision in early April 2001 to proceed, Galileo will enter its Design, Development, and In-orbit Validation phase (DDV) by the end of 2001 and will then follow the schedule shown in Figure 2.[1]

Figure 2: Galileo Program Master Schedule



Developments in Russia's GLONASS since the last Workshop have focused on restoring the GLONASS constellation to operational capability, including the launch of three new GLONASS satellites. Currently, eight GLONASS satellites are fully functional and are providing healthy navigation signals. Russia indicates that two additional launches of three satellites each are planned for 2001.

To ensure a future role for GLONASS in the overall GNSS architecture, the Russian government has formulated a long-term development program that includes three phases. Phase 1, which will run through 2002, will focus on maintaining the current system at a minimum acceptable operating level, upgrading the ground control segment, and beginning mass production of dual GLONASS–GPS user equipment. Phase 2, which will run through 2005, includes the launch of the first GLONASS-M satellites, with planned seven-year lifetimes, to establish an 18-satellite constellation. Phase 3, which will run through 2010, addresses the next-generation of GLONASS with the development of a new series of GLONASS-K satellites that will be smaller and will have a 10-year lifetime. Throughout these three phases, the range of GLONASS uses is expected to steadily increase.

Additional general developments in the provision of GNSS services since the Bermuda Workshop include the following:

- A continued commitment to implementing regional space-based GNSS augmentations such as the U.S. Wide Area Augmentation System (WAAS), Europe's EGNOS, and Japan's Multifunctional Transport Satellite (MTSAT)-based Augmentation System (MSAS), despite technical problems related to integrity provision experienced by WAAS in December 1999 and the loss of the first MTSAT in November 1999—MTSAT-2 is scheduled for launch early in 2003;

- Continuing expansion of local-area ground-based augmentation systems used for land and marine transportation sectors and applications in the geophysical sciences, surveying, and geodetic control;

- Successful protection of GNSS spectrum and approvals for new frequency allocations for the Radio-Navigation Satellite Service (RNSS)

[1]On 4–5April 2001 the European Union Transport Council gave a unanimous go-ahead to fund and proceed with the Design, Development, and In-orbit Validation phase of the Galileo program.

at the 2000 World Radio Conference, now available for modernizing GPS and developing Galileo; and

- Continuing growth in the marketplace for GNSS goods and services, with manufacturers in the U.S. and Japan leading the way in the sales of user equipment.

Throughout these technical and programmatic activities, international consultations by standards-setting bodies such as the International Civil Aviation Organization (ICAO), the International Maritime Organization (IMO), and the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) have continued, as have bilateral discussions among the governments of the United States, Europe, Russia, and Japan. Official U.S. and E.U. delegations have met on several occasions to discuss GNSS cooperation, but tangible progress has proven difficult. A U.S. draft agreement on principles was provided to the European Union in October 2000, and a European technical perspective on possible frequency-sharing scenarios was provided to the United States in December 2000.

Discussions between the United States and Japan have taken place under the framework of the Japan–U.S. Joint Statement of September 1998 on Cooperation in the Use of GPS. Most recently, the first plenary meeting under the framework was held in February 2001. This meeting resulted in the Joint Announcement stating both governments' intentions to continue to work closely to promote the use of GPS as a world standard, to exchange information on augmentation systems, and to avoid harmful interference to and prevent misuse of GPS.

Talks between the European Union and Russia have focused on Galileo and GLONASS cooperation. Russia has proposed a scenario for cooperation with Europe that could include an experimental Galileo payload to be flown on a GLONASS-M satellite, the development of common standards for civil navigation signals, and the eventual use of a common space vehicle that would host both Galileo and GLONASS payloads.

Overall, the use of GNSS positioning, navigation, and timing services continues to grow worldwide. The possibility of new service providers in addition to Europe is also increasing, with China's recent launch of two geostationary "Beidou" navigation test satellites that could be precursors to a regional radionavigation satellite system. India has also expressed interest in launching a space-based regional GNSS augmentation, and U.S. firms (Boeing and Lockheed Martin) are contemplating privately financed space-based augmentations.

Given these significant developments since the Bermuda Workshop, the Working Group investigated key issues that must be addressed in order to move toward greater international GNSS cooperation and attempted to develop meaningful, targeted, and specific recommendations that provide an agenda for action.

Findings and Recommendations

Interoperability

Finding 1—The European Union, the United States, and Russia have embarked on the development of future autonomous GNSS architectures that should also be complementary and interoperable if they are to provide the maximum benefit to users worldwide. Achieving this result requires a level of understanding among the parties that is greater than currently exists.

Three separate next-generation GNSS architectures are currently being studied in the United States, the European Union, and Russia. There is general agreement that these future GNSS architectures should be interoperable, but there is little specific agreement on what interoperability means or how it should be accommodated in system architectures. There is a pressing need to develop a clear understanding of the level of interoperability desired among the systems, and to reach agreement on affected technical aspects of the various system designs.

GNSS interoperability can occur on a number of different levels, ranging from simple signal noninterference of autonomous systems to a complementary and interoperable "system-of-systems." These increasing levels of interoperability can yield increasing benefits to users of GNSS services, but also require increasing levels of technical, managerial, and operational cooperation on the part of the nations developing the systems.

The current situation with GPS and GLONASS is an example of the first level of interoperability (noninterference). These systems were designed independently and with little consideration given to interoperability other than selecting operating frequencies that would not result in mutual interference. Even so, technology has advanced to the point that dual GPS–GLONASS receivers are now available. If next-generation systems place the full burden of interoperability, other than noninterference, on receivers, added benefits to users are likely to be less than optimal.

The next level of interoperability occurs at the system level and can yield improved user benefits from multiple autonomous GNSS systems without extensive technical coordination or cooperation among the nations developing the systems. What is required is an appropriate selection of frequency plans and noninterfering signal structures, and provision of time and geodetic corrections by either the core systems or by coordinated augmentation systems.

To achieve the greatest benefits for future users of GNSS, however, a system-of-systems approach to developing and operating fully interoperable and complementary next-generation systems will be needed. This level of interoperability would allow GNSS receivers to generate high quality, high integrity position or velocity solutions using a composite mix of viewable satellites from different systems, but also requires a much greater level of understanding than currently exists between the United States, the European Union, and Russia. Unfortunately, the open communications required to reach this greater level of understanding has been hampered by differing views between the United States and European Union over the basic approach to cooperation.

The U.S. view on cooperation is that agreement on the following fundamental policy principles will help define the boundaries for system designs, and must precede and guide detailed technical discussions:

- No direct user fees for civil and public safety services
- Open, market-driven competition for user equipment and applications
- Open signal structure for all civil services to promote equal access for applications development and value-added services
- Protection of the current radionavigation spectrum from disruption and interference
- Use of GPS time, geodesy, and signal structure standards
- Seamless, global interoperability of future systems with GPS
- Recognition of national and international security issues and protection against misuse

The United States is also concerned that the E.U. approach to public–private partnerships for funding the Galileo system could lead to anti-competitive regulatory measures to ensure adequate revenue streams.

The E.U. view of cooperation is that technical and policy discussions are synergistic, with technical discussions often shedding light on important policy issues and vice versa, thus helping to define possible solutions. Therefore, both levels of discussion should be pursued concurrently. As evidence of the success of this approach, Europeans point to their parallel technical and policy discussions with Russia on potential cooperation between Galileo and GLONASS.

With Galileo preliminary design scheduled for completion at the end of 2001, it is critical that agreement is reached soon on a number of issues if we are to achieve optimum interoperability, and therefore, the greatest benefits for GNSS users. These include timing and geodesy standards, spectrum sharing and frequency use plans, specific signal structure characteristics, service levels, and integrity approaches.

Recommendation 1—The European Union, the United States, and Russia should reach a common view on system interoperability that is consistent with the design schedules of the Galileo, GPS-III, and GLONASS-K programs.

Institutional Models for Cooperation

Finding 1—The current organization and management structures supporting GNSS may need to evolve to provide optimum exploitation of new and emerging GNSS architectures.

As future GNSS architectures are being developed in Europe and are evolving in the United States and Russia, the need for an international framework to support operational coordination and exchanges of information among system designers and operators and with national and international user communities may be increasingly important. Among the functions such a framework could support are the following:

- Dissemination of GNSS system status information such as satellite health and satellite maintenance and testing schedules,
- Coordination of satellite constellation management to avoid discretionary scheduled activities that might degrade service to users of more than one system,
- Collection of service requirements from the user community,
- Provision of timely notification of service denial, and
- Development, coordination, and exchange of standards for certification of user equipment and augmentation services.

The options for an institutional framework range from informal public- and private-sector coordination mechanisms to more formal intergovernmental structures created by international agreements. Examples of existing organizations that already perform some of the aforementioned functions at a national or regional level include the following:

- The U.S. Civil GPS Service Interface Committee (CGSIC), led by the U.S. Department of Transportation, and supported by the U.S. Coast Guard Navigation Center
- The recently established U.S. DoD User Support Center
- The U.S. GPS Industry Council, Japan GPS Council, and the Scandinavian GNSS Industry Council

Several major multilateral space cooperation projects and programs were suggested as models worth study by an organization with experience in space-related activities. They include the COSPAS/Sarsat search and rescue satellite program, the International Space Station endeavor, and meteorological satellite coordination involving the U.S. joint civil–military National Polar-Orbiting Operational Environmental Satellite System program (NPOESS) and Europe's Eumetsat. Because none of these appear to be an exact fit for GNSS, the more flexible and less cumbersome aspects of each should be emphasized.

Recommendation 1—The AIAA should lead an assessment of current institutional models of international cooperation and coordination and identify those with potential applicability to evolving GNSS systems and services.

Integrity Provision

Finding 1—Multiple levels of GNSS integrity services are currently provided by separate augmentation systems designed to meet the specific needs of the various transport sectors, and are tied to the liability regimes established by national agencies responsible for these sectors. Future GNSS architectures may provide these integrity services as part of the core GNSS design.

Integrity refers to the "usability" of the GNSS signals, which can be affected by errors in timing and estimated satellite positions (ephemeris), signal generation (waveform) anomalies, ionospheric distortion, and other sources of interference, both intentional and unintentional. The integrity of a GNSS service can be critical to certain classes of users, especially in safety-of-life applications such as transportation, which have the most demanding integrity requirements.

The U.S. approach to integrity monitoring and reporting for GPS has been to establish separate geostationary satellite-based and ground-based augmentation systems that broadcast integrity information on a local or regional basis to meet the needs of the various modes of transportation such as aviation, rail, and maritime shipping. This approach also provides an opportunity for nations to maintain sovereignty over their own integrity monitoring and reporting systems.

The current baseline Galileo architecture proposes to broadcast various levels of integrity information, including a global integrity message, directly from the Galileo satellites as value-added services that would be accompanied by guarantees. Within the GPS-III architecture studies, the United States is also considering alternatives that include provision of integrity services directly to global users from the GPS satellites. There may be opportunities for coordinating the integrity requirements of global transportation users of GNSS that could be beneficial to both GNSS users and service providers. These opportunities should be explored as soon as possible if they are to have a substantive impact on the design of next-generation GNSS systems.

Recommendation 1—International transportation standards organizations such as ICAO, IMO, and others should develop a common understanding of integrity requirements and determine if common global integrity standards are feasible and/or desirable.

Spectrum Protection

Finding 1—GNSS service providers need support from user nations to protect the spectrum used by GNSS signals from interference and reallocation for other uses.

Navigation satellite signals are inherently low-powered and are susceptible to interference from other radio frequency sources. With the limited availability of frequency spectrum, and its high commercial value, a number of attempts have been made to either reallocate or share the current GNSS spectrum with other services. Fortunately, the 2000 World Radio Conference was successful in suppressing efforts to share the existing GNSS allocations with other services, and allocated adequate spectrum to meet current and planned GNSS needs. Nevertheless, the need for vigilance in protecting against harmful interference and reallocation still exists and is a responsibility that requires the support of all nations with a vote in the International Telecommunications Union (ITU) process and users who require assured access to GNSS signals.

As a direct result of the previous Workshop's recommendation to include support for increasing the awareness of GNSS benefits in developing nations within the U.N. Space Applications Program, the Office of Outer Space Affairs, with assistance from the U.S. Department of State, has embarked on a series of workshops to discuss the use of GNSS in developing nations. The planning of these workshops is now underway, and a unique opportunity exists to add the need for spectrum protection to their agenda.

Recommendation 1—The U.N. Office of Outer Space Affairs should emphasize the need for support in protecting the GNSS spectrum in its GNSS educational workshops in developing nations.

Finding 2—Recent investigations in the United States have shown that proposed ultrawideband (UWB) systems can cause harmful interference to GNSS signals.

Ultrawideband (UWB) is a form of wireless communications technology that broadcasts an extremely short time-duration burst of radiofrequency energy over a wide band of frequencies. These systems promise to be useful for a number of applications such as ground-penetrating radar, through-wall imaging devices, proximity warning, and possibly wireless local area networking. In contrast to the normal means of introducing radiocommunications technology into the commercial marketplace, which involves specific frequency allocations and regulatory controls, the U.S. Federal Communications Commission has sought test data and commentary on a proposal to allow the unlicensed operation of UWB devices across all frequency bands, including the restricted bands used by GNSS.

Testing completed to date by the U.S. National Telecommunications and Information Administration has revealed that UWB devices with certain broadcast characteristics will interfere with existing systems used for safety-of-life applications, such as air traffic control systems, and will also interfere with GPS receivers used for many applications.[2] Within the United States, public and private sector organizations within the GPS community have long suspected that this would be the case, and have

[2] Anderson, David S., Drocella, Edward F., Jones, Steven K., and Settle, Mark A., "Assessment of Compatibility Between Ultrawideband (UWB) Systems and Global Positioning System (GPS) Receivers," NTIA Special Publication 01-45, U.S. Dept. of Commerce, March 2001; and Roosa, Paul C.,Jr. , et al., "Assessment of Compatibility Between Ultrawideband Devices and Selected Federal Systems," NTIA Special Publication 01-43, U.S. Dept. of Commerce, Jan. 2001.

called for careful testing to be followed by prudent measures to protect the use of GNSS from harmful interference caused by UWB operations.

Within Europe, the European Conference of Postal and Telecommunications Administrations (CEPT) is also considering the appropriate introduction of UWB technology. EUROCONTROL (the European Organisation for the Safety of Air Navigation), which is responsible for overseeing air traffic control in the upper airspace of 30 affiliated member countries, has concluded that UWB systems should not be permitted to cause harmful interference to aeronautical radio services. Furthermore, UWB should not claim protection from aeronautical radio services and should be excluded from operating in aeronautical safety bands unless noninterference can be proven by analyses and test trials.[3]

Recommendation 2—Measures should be taken to protect the frequency bands allocated to GNSS from interference caused by UWB operations.

Safety and Security

Finding 1—Hostile uses of, or threats against, any GNSS service could pose a threat to national, regional, or global security.

The dependency of users on GNSS is comparable to if not greater than other familiar services, such as telecommunications services. The intentional disruption of GNSS services could, therefore, pose great risks to users that could lead to life-threatening situations. Such intentional disruptions could be hostile in nature, or they could be the result of necessary actions taken by sovereign nations whose national security may be at risk from the potentially hostile use of GNSS by other nations or terrorists. Such denials of service, even for appropriate national security reasons, must not jeopardize the safety of civil users. Therefore, all nations (either service providers or users) that engage in service denial carry a responsibility to give timely and appropriate notification to GNSS users affected by their actions.

Recommendation 1a—National and international procedures should be developed to inform affected users when GNSS-based navigation services are denied for security reasons.

GNSS is inherently dual-use in its nature. With access to highly advanced receivers, the same signals that help guide you to your destination in unfamiliar cities can be used to guide ballistic missiles to their targets. Conversely, with access to sophisticated jamming equipment, a terrorist could disrupt civil aviation operations around a busy airport, threatening the lives of innocent civilians. To prevent hostile GNSS use or disruption, the trading and spreading of advanced technologies that can be used for hostile purposes should be closely controlled by national governments that provide and use this equipment. However, the export control regimes that these governments currently apply are different in scope and nature. These differences cause gaps in global export controls and could lead to threats as described.

Recommendation 1b—National governments should engage in a dialogue to ensure harmonization of multilateral export control regimes applicable to GNSS user equipment and signal denial technologies.

Liability

Finding 1—The legal issues surrounding the global provision of satellite navigation services are complex, far-reaching, and have not been sufficiently investigated by the current providers of GNSS services and equipment.

There is a growing recognition that there are complex issues associated with the potential liability for damages caused in the course of providing GNSS services. Although it does present unique challenges, GNSS is not a special case from a legal standpoint. The same liability regime applies to GNSS that applies to other navigational aids, communications systems, and other examples of technology that rely on receiver equipment and radio signals. Since public and private organizations involved in the provision of GNSS services include the full range of service providers, value-added applications providers, receiver equipment manufacturers, and end-user systems integration, each of these organizations must determine appropriate means to provide themselves with adequate liability protection.

The relative applicability of various existing legal principles such as the reliance doctrine, the concept

[3] Pelmoine, C., "Some Elements for Rule Making Regarding UWB Technology," EUROCONTROL, DIS/COM, 9 Jan, 2000.

of sovereign immunity, product liability, and liability laws of various jurisdictions remains unresolved. As the relationships between these and other concepts are studied and become better understood, they become less political and controversial, but still should be fully explored and explained to potential users to ensure the acceptance of GNSS services worldwide.

Recommendation 1—Public and private organizations involved in the provision of GNSS services should strive to understand their roles and responsibilities in the current and evolving global liability regime.

User Support Within Developing Nations

Finding 1—Developing nations are becoming increasingly aware of the costs, benefits, and potential limitations of GNSS services and their applications.

GNSS signals are increasingly used by developing countries for a variety of applications. Recommendations from the Workshop in 1999 influenced the U.N. Office of Outer Space Affairs and the U.S. Department of State to initiate workshops for education and training on GNSS in developing countries. An increasing level of awareness and usage can be seen in these countries, and many examples of highly innovative GNSS applications are found in many developing countries today. Even greater levels of awareness will be fostered through the U.N. workshops, especially if this effort can receive continued support and expansion to countries not currently included in the workshop series.

However, to achieve the greatest benefit from GNSS applications, the governments of developing countries must play a role in ensuring that their users are aware of and receive an adequate level of GNSS service. An appropriate level of service and support from the governments could be assured by initiatives such as the following:

- Investment in national differential GNSS networks that monitor core GNSS signals and provide increased levels of integrity,
- Development of methods to detect and mitigate interference to GNSS signals, and
- Establishment of public or private organizations to support GNSS users through education, information dissemination, technology development, and the implementation of standards for GNSS user equipment.

The U.N. workshops could include discussions of these needs as part of their outreach to developing countries, but it is ultimately the responsibility of governments to ensure that their users are getting the greatest benefit from GNSS.

Recommendation 1—To secure optimal benefits and safe operation for users, the governments of developing nations using GNSS services should seek to ensure that their users receive appropriate levels of service.

Conclusion

Satellite navigation systems that were initially developed primarily for military purposes have resulted in civil applications and markets that today are driving the evolution of these systems and the creation of new systems such as Galileo. The principal driving forces are the following:

- Rapidly growing markets for GNSS equipment and services
- Improving user equipment with decreasing prices
- Increasing dependence of civil users worldwide on GNSS services, especially in safety-of-life applications such as transportation
- New applications that are no longer related to traditional positioning and navigation functions

The inherent dual-use nature of GNSS, defined as either dual civil–military use or dual governmental–commercial use, creates important challenges for international cooperation that preclude the possibility that a single international organization could ever manage and operate a single GNSS architecture to meet the needs of all users. However, the responsibilities of governments, manufacturers, and users of GNSS are becoming clearer and more distinct, and an awareness of the need for end-user involvement in system requirements definition and spectrum protection is spreading worldwide.

Major milestones in the development of next-generation systems are rapidly approaching. Decisions to be made in the near future on GPS III, Galileo, and GLONASS-K will have far-reaching implications for end-users worldwide. To achieve the maximum benefit for all GNSS users, efforts should be intensified to maximize the interoperability of these next-generation systems.

THE WORKING GROUP ON SPACE AND THE PUBLIC: A CRITICAL LINK

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MANDATE

Develop, on an international basis, an implementation methodology for promoting continuous public awareness of the benefits and excitement of space activities.

EXECUTIVE SUMMARY

Space activities are an essential part of the management of planet Earth and the evolution of society. Space has also proven its potential to promote global cooperation and healthy competition. For example, at this time, a multinational, three-person crew inhabits the International Space Station 120 miles above Earth, while on Earth the global economy includes robust competition facilitated by space-derived technologies such as telecommunications, space-based Earth observations, and launch services.

In addition, the excitement of discovery that space provides is incomparable. From Galileo's early observations to magnificent images provided by the Hubble Space Telescope, the question of what lies beyond the stars has driven us to expand our horizons and has improved our knowledge.

Space also provides a sense of adventure. The images of astronauts and cosmonauts flying into space, floating in a microgravity environment, and exploring the space frontier excite children and adults alike. This element—human space travel—has always been and will remain one of the most appealing and motivating aspects of space activities worldwide.

Although space is integrated into many facets of daily life, the general public's knowledge of and support for space activities is not commensurate with the benefits that are derived from them. Therefore, space agencies, the aerospace industry, and space-related entities, share a common challenge: To communicate better the contributions of space to society and the excitement of space exploration and discovery.

In response to this challenge, the Working Group recommends that the space agencies of the world establish cooperative, international mechanisms to promote and coordinate the implementation of long-term communication and outreach. This would be accomplished by engaging parties at all levels of the space community, leveraging education programs and products, and capitalizing on public outreach opportunities worldwide. Crafting and delivering clear messages directed at decisionmakers and the general public would be a significant step forward. The need also exists to develop and equip a new generation of spokespersons who can deliver this message in a credible and exciting manner. The Working Group calls particular attention to the importance of engaging youth as an integral part of this endeavor.

BACKGROUND

Space activity has moved from its initial role as a prime vehicle for displaying ideological and military supremacy, positioned right at the leading edge of science and technology, to that of being applied increasingly to direct benefit of many aspects of society's development. However, the space community has been unsuccessful in creating general awareness that the current influence of space activity on society is even more significant than in the days of the space race. Although overall government expenditures on space activity remain reasonably steady and significant, and commercial activity is increasing annually, space activity appears less and less on the political agendas of developed nations. Moreover, it does not provide the level of short-term financial returns required to attract enough private investment to allow a significant expansion of commercial space activities. The real need for space activity continues, but general interest in its development is today insufficient.

Space activity is an essential component of the information age, enabling the global collection, distribution, and use of data and information. This information age is having a profound influence on the world. It is an age of gathering, creating, and sharing knowledge about the world and its environment on an unprecedented scale. This new reality is raising expectations, changing social habits, changing population growth rates and demographics, and making all people acutely aware of the limitations of Earth's ability to support unchecked human demands. It is changing the quality of human and other forms of life.

Human necessities include food, water, shelter, education, health care, energy, communications, transportation, security, and a sense of adventure. The quality of human life is further enhanced through societies' systems of ethics and justice and through economic well being. It is astonishing how much human space activity, in its short existence, has become integrated into each of these aspects of life and how it will, in future, allow many of them to continue to be accommodated within the ever-increasing restrictions imposed by a world that is to remain sustainable.

Space activity also enables unprecedented exploration of the environment around Earth and is extending this exploration ever deeper into our universe. It addresses part of the basic human needs for knowledge, motivation, and adventure.

During the coming decades, humanity will have the opportunity to achieve truly profound strategic goals in space exploration, utilization, and development. We shall make possible the permanent extension of human presence beyond the bounds of Earth and enable fundamental improvements in our understanding of our solar system and the universe (and in the quality of life here on Earth). We shall be building on the firm foundation of a completed, initial exploration of the solar system, strong, internationally diversified space launch capabilities, highly capable and exciting space and Earth science and applications missions, the International Space Station, flight experience in low Earth orbit and human exploration of the moon, extensive space communications capabilities, comprehensive Earth observation and navigation systems, as well as excellent ground infrastructures and laboratories.

Change is required in the space community's approach to outreach efforts if it wishes to effectively position space activity as one of the most important human endeavors of this century. Messages need to be developed that focus on the capacity of space activity to facilitate the achievement of a sustainable world in which the necessities of life are available to all and quality of life is assured. In addition, emphasis needs to be placed on the unique capabilities and capacities of space activity to allow humans to explore and search for knowledge beyond the bounds of Earth. Space activity must be more generally recognized as essential to human well being and considered, particularly by the young, as a worthwhile and satisfying career path. In short, space activity must come to be widely seen as essential to a sustainable world and to evolution of human society.

The Working Group addressed how this might be achieved.

Findings

Finding 1—Space activities are not accorded the priority they merit with respect to the contributions they make to society.

Few people understand the extent to which space activities influence modern life. Many aspects of weather forecasting, environmental monitoring, telecommunications (e.g., worldwide television broadcasting), and navigation are only possible through the use of space systems.

Finding 2—Although research shows broad public support for space activities, this support is passive.

As noted in the background information, public opinion polls overwhelmingly show that the public supports space activities. However, the depth of that support is sometimes questionable. When asked if they support space activities, the majority of people respond positively. When space competes with other priorities such as medical research, welfare, or education, the priority given to space relative to these other areas is lacking. In government space sectors around the world this lack of public support has led to stagnation in budgets, which precludes real advance.

Finding 3—The communication paradigm has changed, but is not globally uniform.

In the developed world, information access and delivery has changed substantially as a result of new developments in telecommunications capability. A dramatic expansion of information sources has occurred. Web sites and cable channels allow individuals to obtain unlimited access to information, seven days a week, 24 hours a day. Although the number of communication mechanisms has increased, competition for exposure has also increased, making the task of selling your story more competitive. The pace of news delivery has also changed, requiring short, simple phrasing (the 7-second sound bite). Further, the number of knowledgeable and experienced members of the scientific press has decreased.

The level of change in this area is variable throughout the globe. In some developing countries, access to the Internet and significant television programming is virtually nonexistent, and the principle communications mechanism remains the printed word. Any future communications strategy must take this into account and recognize that any international communications effort will be implemented on regional and local levels. Therefore, the methods and mechanisms available at those levels must be considered.

Finding 4—Internationally coordinated outreach of space activities has been conducted with mixed results.

The environmental movement presents a good example of how a communications campaign can be coordinated internationally. For more than 30 years, Earth Day has been celebrated worldwide. As a result of such efforts, the message to protect the Earth has been delivered and adopted by a global audience. The success of these global efforts was the result of local, regional, and national implementation.

The 1992 International Space Year (ISY) also provides an example of an internationally coordinated public awareness endeavor that was coordinated at an international level and implemented nationally and locally. One of the successes of the worldwide celebration of space was the communication of agency-developed education products and programs that were leveraged by various organizations in numerous countries.

Although the ISY did bring space agencies together in this area, it fell short of engaging the public and leveraging its momentum into a long-term advantage. Any future effort should focus on audiences outside the space community and take a long-term view of this important task.

Finding 5—Interest is increasing within the space community to address the outreach challenge.

Throughout the space sector, individuals as well as agencies and professional societies are attempting to improve their education and outreach efforts. Whether it is an astronomer trying to draw attention to the threat of asteroid to Earth, or an astronaut trying to motivate young people to study math and science, enthusiasm, efforts, and ideas are endless. This was illustrated at the Workshop as numerous members of other Working Groups requested to share their ideas and experiences with Working Group 4.

Recommendations

Recognizing the need to establish cooperative, international mechanisms implement long-term communication and outreach, the Working Group urges :

Recommendation 1—Space agencies of the world should take the lead in revitalizing collaboration amongst themselves, industry, space-related organizations, and academia to improve public outreach.

The Working Group recognizes that communicating the benefits of space for the management of planet Earth and the excitement of exploration and discovery is the responsibility of the entire space community. There are, however, those entities that are better positioned to initiate and influence this effort. Although not extremely active at this time, the Space Agency Forum (SAF) includes a membership of 23 of the world's civil space agencies and a mandate to promote better coordination among those organizations, specifically in education and outreach. Therefore, the Working Group recognizes SAF as providing the best opportunity to implement this endeavor.

The Working Group recommends that SAF lead the effort and engage other organizations that play critical roles. The International Astronautical Federation (IAF) includes some 150 international industry members and academic, scientific, and government space representatives. Their annual meetings could be leveraged to promote the use of consistent and accurate outreach messages. Other organizations such as the U.N. Office of Outer Space Affairs (UN/OOSA) International Academy of Astronautics (IAA), and the International Institute of Space Law (IISL) could also play active roles.

On national, regional, and local levels, the AIAA, the Aerospace Industries Association, the Confederation of European Aerospace States, the European International Space Year (EURISY) organization, and Asia-Pacific Rim Space Agency Forum are poised to reach specific audiences and implement proactive outreach.

Efforts should be made to ensure that other organizations such as those in developing countries (e.g., Latin America) are identified and engaged.

Recommendation 2—All space organizations should exploit education programs and products to improve the public's understanding of the significance of space achievements.

The Working Group felt strongly that science and technology education must be improved and space incorporated into the basic education of children in order to enrich the general public's appreciation of space achievements. One example identified by the group was NASA's recent Near-Earth Asteroid Rendezvous Mission (NEAR). When the public better understands what an asteroid is, how it moves through the solar system, and the technological challenge of landing a small spacecraft on a tiny rock in outer space, comprehension and appreciation of the accomplishment will be enhanced.

An abundance of space-related education programs are being conducted worldwide. Programs such as those offered by Indian Space Research Organization, National Space Development Agency of Japan (NASDA), EURISY, the Challenger Centers, and other dedicated venues, are greatly contributing to expanding this understanding. In addition, they inspire a general, young audience to learn more.

Recommendation 3—The community should identify, develop, and promote spokespersons who can deliver messages on behalf of the space sector.

The messenger in the communication process is sometimes just as important as the message. The role of the "goodwill ambassador" for space exploration filled by Carl Sagan, and for oceanography and the environment by Jacques Cousteau, is now largely absent in the space community. Therefore, articulate, credible, and engaging spokespersons are essential to improving the communications mission.

Not only are spokespersons needed at a highly visible level but they are also needed at other levels. Whether the spokesperson is addressing policy makers, industry representatives, or school children, he or she should be aware of key messages, deliver information in an exciting manner, and be equipped with colorful and interesting materials.

Organizations such as the Association of Space Explorers can be tapped to help respond to this need.

Recommendation 4—The community should capitalize on opportunities to maximize public awareness and participation.

Numerous opportunities already exist to promote public awareness. For example, World Space Week—scheduled for 4–10 October annually—presents an excellent venue to capitalize on an ongoing effort in an expanded way. The IAF and other organizations should make every effort to open their conference exhibits and expose the public to space topics, research, and technology and should advertise and promote such opportunities through local media. Funds invested in museum exhibits could be greatly leveraged if such exhibits were shared through international networks.

Recommend 5—The community should identify and share best practices.

Many space organizations and agencies are taking new approaches to public outreach. NASA, for example, recently began to dedicate a percentage of mission or research project funds to outreach and education. In addition, some organizations recognize the importance of providing science and technical representatives with communications support. NASA has also developed means to recognize science and technical representatives who participate in outreach and communication. These practices, and others of which the Working Group is unaware, could be assessed for their applicability to other organizations.

Recommendation 6—Space organizations should engage mass media experts to help shape messages and assess marketability of the messages.

The basic processes for communicating space information are no different from those of any other media message despite space's many unique characteristics. Therefore, this community should take advantage of existing media expertise to formulate and package the communication. This is extremely important in assessing the effectiveness of this effort.

Of particular importance is the need to target and reach distinct audiences such as the general public, media, opinion formers, and decisionmakers. Emerging audiences such as citizens in developing countries and complementary interest groups must also be appropriately addressed.

The main message identified by this group is that space activities are an essential part of the management of planet Earth and the evolution of society. Additional messages are as follows:

- The benefits and opportunities space presents are an intrinsic part of society.
- Although space efforts are perceived as routine and part of everyday life, innovative technology is challenging and sometimes can fail.
- Exploration for the sake of discovery is an admirable goal and should be embraced.
- Careers in space-related fields are rewarding and satisfying and contribute to the management of our planet.

Recommendation 7—The community should exploit global communication mechanisms for the purpose of reaching decisionmakers worldwide.

The audience of global communication mechanisms such as BBC World News, CNN, and the Herald Tribune could be exploited not only to reach a broader multinational audience but also to reach and influence opinion formers and decisionmakers.

Recommendation 8—The community should engage youth to help promote outreach.

The Working Group gave special emphasis to the importance of the youth audience. Space agencies as well as the United Nations have efforts underway to engage this group. Examples are the European Space Agency's (ESA) strong support of the International Space University and ESA's program to send large numbers of students to the annual IAF meeting. These and other efforts should be a priority in this recommended communications effort. Because this audience represents the future workforce and the major beneficiaries of today's investment, every effort should be made to contribute to their knowledge, sound citizenship, and capability to manage Earth and exploration of the unknown.

Conclusions

The Working Group concludes that internationally coordinated outreach is essential for the following:

- Increasing awareness that space activities are an essential part of the management of planet Earth and the evolution of society
- Maintaining or elevating the priority of space activities on national agendas
- Delivering consistent and accurate messages via the broad media
- Leveraging investment in professional conferences by engaging the public
- Making space an integral part of school curricula and leveraging that investment
- Enticing more young people into space-related careers

The Working Group also recognizes that long-term action is a necessity as results may not be achieved in the short term. Therefore, it must be recognized that this effort is a long-term commitment requiring the participation of the broad space community.

For these recommendations to become a reality, the Working Group identified three, near-term steps for implementation:

Task 1—Urge SAF to take the lead in revitalizing communication, cooperation, and collaboration amongst space agencies, industry, space-related organizations and academia to improve public outreach.

The Working Group agreed that SAF has the unique mandate and membership to carry out the recommendations put forward in this report. As noted in the SAF's Terms of Reference, one of its key objectives is to "...seek to enhance creative and cost-effective international cooperation among the space agencies by exchanging information on programmes and plans ... Public Outreach and Education"

Task 2—Capitalize on near-term opportunities to communicate Working Group findings and recommendations, and solicit feedback.

The Working Group identified several venues where these findings and recommendations could be delivered. For example the upcoming meetings of the Space Agency Forum and the International Astronautical Federation in October 2001 were identified. The meeting of the ISS Public Affairs, scheduled for June, could also be used. In addition, it was suggested that the AIAA and CEAS organizations host CEO-level meetings for industry.

An effort also should be made to identify venues in other parts of the world (e.g., Asia) to deliver the meeting results. Plans are underway to transmit this report to the United Nations.

Task 3—Establish through the AIAA International Activities Committee a group to receive and assess feedback and to facilitate program development.

As the facilitators of the international workshop that has led to these recommendations, the Working Group identified the AIAA International Activities Committee as the appropriate body to monitor the progress of these recommendations.

THE WORKING GROUP ON
THE CONTRIBUTION OF SPACE SYSTEMS TO THE DEVELOPMENT AND IMPLEMENTATION OF MULTILATERAL ENVIRONMENTAL AGREEMENTS

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MANDATE

Examine the role of civil, governmental, and commercial space systems in the development and implementation of multilateral environmental agreements and the impact these systems could have on negotiation of future agreements.

EXECUTIVE SUMMARY

The Working Group on The Contribution of Space Systems to the Development and Implementation of Multilateral Environmental Agreements examined the role that space-based Earth observation (EO) systems could play in environmental agreements. The Working Group looked at ways to improve the integration of EO data and information throughout the entire process of developing and implementing these agreements. More than 200 multilateral environmental agreements (MEAs) addressing environmental issues and concerns have come into existence during the past few decades, but few explicitly incorporate or depend on EO data and information.

An overarching conclusion of the Working Group was that EO systems provide objective data that are frequently unique and that provide the additional advantage of yielding global, homogeneous, and repetitive coverage. The MEA community can beneficially use these data and the information derived from them. In particular, EO systems observe and monitor activities and changes in land, ocean, and atmosphere phenomena such as deforestation, ocean circulation, and depletion of stratospheric ozone. In many cases, EO data and derived information products can be used to assess the effectiveness of MEAs in achieving their environmental goals and to verify compliance.

The Working Group highlighted the desirability of greatly strengthening communications between the EO and the MEA communities. The EO community should learn more about the needs of the MEA community, whereas the latter should learn more about EO capabilities to better understand and appreciate what can and—just as important—what cannot be done with EO data and information.

The Working Group's recommendations encompassed a variety of encouragements and actions for the EO and MEA communities to enhance communications, to develop appreciation for each other's needs and capabilities, to take advantage of each other's expertise in ongoing forums, to work together to improve potential MEA parties' understanding of and confidence in EO data and information and its uses, to undertake joint action to help ensure operational continuity of required data and information from EO systems, and to network organizations to distribute responsibilities for operating space systems and for distributing data.

BACKGROUND

Multilateral environmental agreements are developed among governments to collectively address environmental concerns. As with other treaties and international agreements, they are tools for accomplishing policy objectives commonly held among the parties, and they generally include formal, binding commitments. Some of these agreements deal with the global commons, addressing, for example, such problems as ocean pollution, ozone depletion, or global climate change. Others focus on environmental problems of a regional or local nature that impact the territories of sovereign states but that raise international concerns, such as deforestation, desertification, various types of pollution, and scarcity of water resources.

Examples of major agreements include the Antarctic Treaty (signed in 1959) with its subsequent Protocol on Environmental Protection (1991, but not yet entered into force); the Ramsar Convention on Wetlands (1971); the International Convention for the Prevention of Pollution from Ships (1973); the Vienna Convention on the Protection of the Ozone Layer (1985) and its subsequent Montreal Protocol on Substances that Deplete the Ozone Layer (1987); the Convention on Biological Diversity (1992); the U.N. Framework Convention on Climate Change (1992) and its subsequent Kyoto Protocol (1997, but not yet entered into force); and the Convention to Combat Desertification (1994). These conventions and protocols lay down objectives in terms of results to be achieved concerning the environment and in terms of actions to be taken to achieve these results. And many create an international organization to administer the agreements, often called a secretariat.

Space-based EO systems include Earth-observing sensors and satellites, along with associated ground-based receiving and processing systems necessary to transform observation data into information products.These EO systems are a tool, developed in recent decades, that has become essential for effectively conducting many types of environmental management and research applications. They provide reliable, factual, consistent, recurrent, and timely information on a global scale that may be used to map areas of interest, provide measurements of certain key parameters, and monitor the evolution of studied phenomena.

Information from other types of space systems, such as communication satellites, data relay systems and GPS, and other related sources of data and information collected by aerial, ground, and subsurface systems are also contributing to the understanding of the environment. However, the objective of this Working Group was to assess the potential value of EO data and information to policy makers and negotiators involved in the development and implementation of MEAs.

Findings and Recommendations

Finding 1a—There is a strong foundation in law supporting the use of data and information from EO systems in MEAs. The basis for this international legal status includes international space law as well as national laws, customary law, and the application of equity principles. This body of law permits and encourages the peaceful uses of outer space by governments, intergovernmental organizations, and nongovernmental entities.

Since the dawn of the space age, governments have adopted several treaties and U.N. resolutions that define and expand the legal use of space. The first, and most important, of these is the 1967 Outer Space Treaty. Among other things, this treaty establishes that there is freedom of scientific investigation in space; all nations have the nonexclusive right to use space; no nation may appropriate space or exclude another from its use; and intergovernmental organizations and nongovernmental entities also have the right to use space.

The activities of EO systems have been accepted as a legal use of space since the early 1970s. The rights and obligations of nations that conduct Earth observations and nations that are sensed by satellites and space-based platforms were specifically addressed in the 1986 U.N. Principles on Remote Sensing, which were unanimously adopted as a resolution by the U.N. General Assembly. Although not yet formally adopted as a treaty, these principles have achieved the status of customary international law and have been formally incorporated into the domestic laws of some Earth-observing nations, such as the United States and Japan, as well as in many bilateral and multilateral cooperative agreements regarding EO missions and programs. They define remote sensing as the sensing of the Earth from space for the purpose of improving natural resource management, land use, and the protection of the environment, and they stipulate that data concerning the territory of a sensed state must be available to it on a nondiscriminatory basis and on reasonable cost terms.

The space treaties and remote sensing principles are based on, and are a part of, the larger body of international law that includes all of the treaties, resolutions, customary law, and equitable principles of which it is comprised. The Outer Space Treaty itself incorporates by specific reference all of international law and the U.N. Charter. Moreover, principles of cooperation and the common interests of all nations are of particular relevance in this area and would support the application of the rights and obligations of states in accordance with the principles of equity and justice. It is this body of law, along with the domestic laws of individual nations, that is available to apply EO activities to the development and implementation of MEAs.

Finding 1b—The continuous collection and utilization of data from space are of major public benefit in understanding Earth's environment. EO systems can provide objective, neutral, and transparent data that are in many cases unique and that have the additional advantage of providing a global, homogeneous, and repetitive perspective, frequently on a continuous basis. The data provided by EO systems and the information derived from them therefore are potentially useful in all phases of the process of developing and implementing MEAs, even though the EO activities were not organized to support MEAs specifically.

EO systems now routinely provide observations of Earth's environment at global, regional, national, and local scales and are extremely useful in identifying trends in the environment. Remotely sensed data from space are critical to monitoring and understanding the Earth environment and the effect of humans on it. Although EO systems are by no means the only sources of information about the environment that can be used to support the development and implementation of MEAs, they do provide unique observational capabilities that make them especially valuable for this purpose. Table 1 provides a few examples of applications of EO systems relevant to the MEA process.

Obviously, an MEA includes provisions focused on securing its intended purpose and effects. The application of EO systems to MEAs can range from the identification of an environmental problem, to

Table 1: Examples of Space-Based Earth Observation Systems and Related Monitoring Applications

Current and Future Space-Based Earth Observation Systems	Related Monitoring Applications
Land Remote Sensing Systems: Landsat, SPOT, RADARSAT, IRS, CBERS, IKONOS, EROS-A1 **Future Systems:** RADARSAT-2, SPOT-5, Pleiades/Cosmos-Skymed, SMOS, QuickBird, OrbView-3/4, IRS-2C, VCL	Land cover/land use and conversions, mining activities, vegetation and forest cover, biomass, wetlands monitoring, pollution sources, deforestation/reforestation, desertification
Oceanic/Environmental Systems: Topex-Poseidon, OrbView-2/SEASTAR, EOS-TERRA, Quick-SCAT, ERS,TRMM, IRS-P4 Future Systems: JASON, EOS-AQUA, ICESAT, SMOS, CRYOSAT, GOCE, ADEOS-2	Ocean color/phytoplankton, ocean biota, ocean currents and circulation, surface winds, sea surface temperature, ocean dumping, ship pollution, fishing activities, oil spill detection, ice caps and sea ice characteristics
Atmospheric/Environmental Systems: NOAA/POES, METEOSAT, GOES, GMS, INSAT, ERS, TOMS, TERRA, **Future Systems:** NPP, NPOESS, METOP, ENVISAT, ADEOS-2, MEGHA-TROPIQUES, EOS-CHEM/AURA, AEOLUS, CLOUDSAT, PICASSO/CENA, PARASOL	Ozone mapping and profiling, atmospheric pollution, cloud cover, atmospheric CO_2, stratospheric aerosols, volcanic ash cloud tracking, tropospheric wind profiles

Note: The EO systems in the table provide data that are used for research and operational applications beyond those listed here. For example, atmospheric EO systems provide ocean data such as sea surface temperature.

the monitoring and assessment of that problem, to the verification of compliance and subsequent enforcement.

Prenegotiation Phase

At the most basic level, data and information from EO systems can identify and characterize environmental problems that may not otherwise be recognized or understood. The information from these systems is now beginning to be used to create public awareness and to increase the public's scientific understanding of these problems. For governments to decide to develop an MEA, there needs to be some political recognition that there is strong scientific evidence of an environmental problem, as well as a potential solution. EO data and information can be instrumental in generating the scientific understanding of new environmental problems and the political will to address them.

As a specific example, the media used Nimbus-7 satellite data to document the seasonal depletion of stratospheric ozone over the Antarctic in the mid-1980s. The resultant public awareness and understanding of what was happening to Earth's protective ozone layer was instrumental in galvanizing public support for action. The product was the Vienna Convention on the Protection of the Ozone Layer and the subsequent Montreal Protocol, which led to the elimination of commercial production of ozone layer–damaging chlorofluorocarbons.

Negotiation Phase

Once an environmental problem has been identified, data and information from EO systems can contribute substantially to the MEA negotiation process by assisting negotiators and policy makers to define the scope and specific terms of the agreement, and by making these provisions more acceptable among the parties. For example, the Central American Commission on Environmental Development, with assistance from NASA EO experts, negotiated the MesoAmerican Biological Corridor Agreement in 1998. Landsat imagery showing extensive deforestation on the Mexican side of the Mexican–Guatemalan border, but good forest cover on the Guatemalan side, provided a catalyst for this international memorandum of understanding. The agreement provides for land-cover and land-use assessments, through the production of a satellite-derived base map for the entire isthmus, with a goal of protecting the integrity of ground cover along wildlife migration corridors from Panama to the Mexican border.

It is important to note that not all countries have equal capabilities to acquire and use EO data and information meaningfully. There are many more nations that use, or can use, EO information than there are nations that operate EO systems and generate data. These disparate capabilities may affect the willingness of some parties to negotiate dependence on such data and information in the implementation phase of MEAs. Negotiating parties may need to consider this factor in developing new MEAs.

At the same time, those drafting MEA requirements may need to be assured that the required EO data and derived information will be routinely available as required. It is also important that they have confidence in the validity and suitability of the information for their purposes through the availability of comprehensive documentation and metadata (descriptive information about the observational data sets). Another key issue that MEA negotiators may be concerned about is the transparency of the entire information chain; that is, whether it is open to external scrutiny and can be independently verified. All of these issues will need to be understood to win the confidence of the international community in the more dedicated application of EO data and information to the MEA process.

Implementation Phase

Upon the formal adoption of an MEA by the parties, EO systems can be used to observe, monitor, and assess the effectiveness of implementing provisions of MEAs. Currently, however, the implementing provisions of most MEAs do not specifically reference or depend on specific scientific data, let alone EO data. The Vienna Convention on the Protection of the Ozone Layer was a recent exception to this general omission, reflecting a high level of scientific evidence and consensus about the cause of stratospheric ozone depletion, as well as the existence of EO and other monitoring capabilities.

Finally, the data and information from EO systems can be especially useful in supporting verification and enforcement terms and conditions in those MEAs that contain such provisions. MEAs are tools for accomplishing policy objectives agreed to among the parties. It is understood that the adoption of verification provisions with the goal of determining violations and enabling the possibility to enforce compliance is a political decision that requires consensus and consent by the parties to the MEA. Such a decision depends not only on the availability and reliability of information derived from EO systems and from other relevant sources but also involves consideration of political, economic, and national security factors related to the broad desirability of a verification regime.

At a minimum, the public availability of EO data can deter violations and promote voluntary compliance with MEA requirements by making any party's previously hidden and difficult-to-find transgressions much easier to detect. Furthermore, MEAs that include enforcement provisions should consider the effectiveness of verification capabilities offered by EO systems and related information systems.

Finding 1c—The EO and MEA communities have a common interest in establishing effective communication concerning the benefits, opportunities, and challenges of using EO data and derived information products in the MEA process. However, the connection between the two communities is not yet adequately developed, and consequently, MEA needs and EO space capabilities are not efficiently integrated.

Despite the fact that EO systems increasingly are capable of assisting in the MEA process, this capability has not been fully appreciated and has been underutilized. For example, the Kyoto Protocol to the U.N. Framework Convention on Climate Change requires the setting up of national systems for the estimation of anthropogenic emissions and sinks of greenhouse gases, but parties need to agree on common characteristics for these systems allowing intercomparison. In a similar manner, the U.N. Convention to Combat Desertification requires that the parties integrate and coordinate the collection, analysis, and exchange of data and information to ensure systematic observation of land degradation in affected areas and to understand better and assess the process and effects of desertification, but parties have not yet indicated the ways and means to meet this objective. EO data and information would be useful in both these MEA regimes.

On the other hand, some worthwhile projects have already been undertaken to demonstrate the relevance of EO systems and associated data and information to MEAs. A good example is in the field of oil pollution monitoring of the seas using synthetic aperture radar to support the International Convention for the Prevention of Pollution from Ships. By the same token, EO systems can be very useful in national and subnational environmental legislation, regulation, and other types of environmental policymaking, which can provide a helpful body of practices and experience in applying this technology in the multilateral environmental context.

In any case, the EO community needs to do a better job in demonstrating the utility of EO systems and the information they provide for other applications relevant to MEAs. This will serve to build stronger links between the EO and the MEA communities and will demonstrate to the general public the value and reliability of these techniques.

Recommendation 1a—The EO community needs to learn more about the evolving needs of the MEA community, whereas those who work in the MEA arena need to learn more about EO space capabilities and to better understand what MEA objectives can and cannot be supported using data and information from existing and planned EO systems.

Communication between the MEA and EO communities would be strengthened by engaging in a number of activities, including the following: 1) Developing a detailed cross-correlation, matching specific MEA provisions with relevant space-based EO capabilities to better inform discussions between the two sectors. 2) Carrying out joint pilot projects. 3) Commissioning a series of national and international studies and colloquia that engage experts, negotiators and practitioners in the MEA and EO communities: to examine the use of EO data and information in legislation and regulation, in environmental policy, and in programs at national and local levels; to identify and analyze important lessons learned from previous MEA regimes; and to undertake case studies that simulate the development of MEAs.

Recommendation 1b—The MEA and EO communities should be encouraged to take advantage of each other's expertise in their respective activities.

In this regard, EO specialists should seek to become more involved with their delegations engaged in negotiating new MEAs and in implementing existing ones, for example, by creating or using existing scientific and technical expert groups to work with MEA negotiators and secretariats to advise on the availability, characteristics, and limitations of information sources; to communicate about information systems requirements; to define specific products that meet specific MEA requirements, as well as the methodologies to produce those products; and to monitor the performance of existing information systems, as well as the potential of new information systems, technologies, and methodologies that contribute to MEA implementation. Additionally, MEA negotiating teams should seek the involvement of EO specialists in the MEA process, and secretariats of existing MEA regimes should seek the assistance of the EO community in thoroughly reviewing all aspects of the MEAs (including, in particular, the monitoring, assessment, and compliance provisions) in the context of EO and related data collection and information management technologies.

Recommendation 1c—To optimize the utilization of EO systems, parties to MEAs should identify their information requirements in support of the objectives of their MEAs.

The implementation arrangements of an MEA should establish ways and means to define the specific EO data and information products required, as well as to adapt to developments concerning the observation and information systems (such as creating or using existing scientific and technical expert groups to work with MEA negotiators as mentioned in Recommendation 1b.) The derivation of requirements from an MEA should address the issues of validity, character, and availability of the data and information products, as well as the reliability and transparency of the EO data and information, and the processes used to provide them.

Finding 2—Use of EO data and information for MEA monitoring, assessment, and verification requires that the parties to MEAs have high levels of confidence in the data and information, and thus could necessitate validation requirements beyond those developed for scientific purposes. Scientific and technical standards and practices already exist for many kinds of EO data, particularly from operational systems. Such standards and practices can facilitate and improve the process of developing legally recognized standards for EO data and the use of those data in MEA regimes.

The international meteorological system is the archetype of an operational EO system. It uses EO data in association with other data, and it is based on the distributed structure of both the space segment and the meteorological information system. A set of data and information are exchanged freely and openly among countries under the aegis of the World Meteorological Organization (WMO, a U.N. specialized organization). This organization supports national meteorological requirements while disseminating the data and information contributed by its members for broad international use. Confidence in the system is fostered by the participation of many actors in the production of data and information, the development of related common technical and management standards, and the commitment to exchange such information.

MEAs reflect the willingness of the parties to address environmental problems of common concern and to meet certain obligations. Such obligations are measured against specific methods and standards that are technical in nature and may not be able to be defined or specified within the MEA itself. This creates a need to rely on scientific work already undertaken and related technical standards that are defined and consistently used concerning the observational and information management technologies and practices. As these standards and practices are developed and refined over time, they achieve a higher level of reliability and consistency with regard to their application to MEA regimes. For example, EO data have achieved some formal legal recognition through national court decisions, particularly as specialized scientific or expert sources of evidence, but they have not yet received recognition and acceptance as legal evidence in international law.

Recommendation 2—EO data providers, working in concert with the MEA parties, need to take steps to ensure confidence in the data and information derived from EO systems. Toward this end, distributed information systems, which require common technical and management standards, should be strongly considered. Network structures similar to those used in the international meteorological system should be considered for use in the production of information as well as for research on processing and modeling in support of MEAs. These multilateral partnerships can strengthen the widespread acceptance of EO systems and their information products.

Finding 3—Data and derived information used to develop and implement MEAs can be obtained from public and private, civil and military, and

national and multinational EO systems. Each system has its own characteristics and constraints.

EO systems frequently can meet the needs of multiple types of users, beyond the primary application areas and user groups. For instance, research information on sea-surface winds is used in operational forecasts, and high-resolution land remote sensing images are used in many kinds of research and commercial activities.

By the same token, practically all space-based Earth observing and associated information systems have the capability of supporting some MEA requirements, and the parties to MEAs may wish to make use of relevant information from a variety of such sources. However, the distribution and use of data and information products from some of these systems may be limited because of their classification on national security grounds, or because of commercial proprietary restrictions.

Recommendation 3—The MEA community should consider data and information from all sources. However, recognizing that access to and use of different sources of EO data and derived information must be consistent with the legal rights and obligations that apply to these different systems, the potential value in MEA use of certain data sources may need to be balanced against potential increases in complexity and potential decreases in transparency.

Finding 4—Many MEA objectives would be best supported by long-term, continuous satellite observations. Although both space-based experimental/research and operational EO systems can contribute to the development and implementation of MEAs, only operational systems provide some guarantee of continuity. EO experimental/research missions are not supported by long-term institutional arrangements, and therefore do not ensure the continuity of data consistent with MEA objectives. Although continuity in the collection of data is clearly planned for some areas of EO, other areas are at threat beyond currently approved research missions. For instance, atmospheric chemistry, ocean dynamics, and land-cover dynamics pose urgent data continuity concerns.

An operational space system is one that has been designed to provide continuity of service that is guaranteed by an institutional commitment. The meteorological satellite system, operated on a cooperative and coordinated basis by multiple countries and organizations, is the most mature example of an operational system. On the other hand, an experimental or research space system is of limited duration, typically designed to demonstrate new technology and the utility of specific observational measurements in support of scientific investigations. An example of a research system is TRMM (the Tropical Rainfall Measurement Mission), designed as a three-year cooperative NASA/National Space Development Agency of Japan (NASDA) mission to study the global water cycle and its variability resulting from natural and human-induced change. Although it is lasting longer, the concept behind the mission was never intended to produce a continuous observational record for the indefinite future. A follow-on Global Precipitation Mission (GPM) is contemplated, but not guaranteed.

Observational parameters such as ocean topography, stratospheric ozone concentrations, and land-surface vegetation cover currently are acquired from research satellite missions. These missions have demonstrated the value and uniqueness of space-based observations in providing an accurate and global means to monitor phenomena such as ocean circulation and changes in sea level, the evolution of Earth's protective ozone layer, and the rate and extent of global deforestation. No firm plans exist, however, to ensure continuity in the acquisition of these and many other research datasets, which are of considerable relevance for many MEAs. Moreover, the institutional arrangements for bringing such important data acquisition capabilities to operational status are not yet well defined at either the national or international levels.

Nevertheless, there is a growing recognition of the importance of ensuring data continuity for some missions. The EuroGOOS (European Global Ocean Observing System) Conference, for example, has recommended continued European participation in providing precision altimetry through the Jason-2 mission. The recommendation indicated that this should have the highest priority in the initial implementation of an operational oceanographic satellite system for Europe and also that Eumetsat should adopt the European part of the mission.

Where the implementation of MEAs depends on certain relevant data being collected continuously over many years, MEA negotiators will be obligated to take into consideration both the current and future availability of EO systems and information sources to meet their requirements.

Recommendation 4—The EO community and the MEA community should act together to ensure the institutional continuity of EO space-based information required for the development and implementation of MEAs.

To this end, the allocation of operational responsibilities for meeting the objectives and continuing requirements of MEAs needs to be defined, and arrangements should also be considered to improve the continuity of relevant information initially obtained from experimental/research missions.

Finding 5—The permanent preservation and archiving of data and selected derived information products from EO missions are essential for supporting a broad range of environmental research and application objectives, including their use in many MEA regimes. However, the preservation and archiving of many kinds of EO and related data and information, particularly those that could be responsive to MEA requirements, are not currently assured.

Because the monitoring, assessment, and verification of MEAs frequently require that current data be compared with data collected continuously over many years, the reliable preservation and archiving of datasets is an essential function. A number of very large, reliable, and continuously updated data archives in fact already do exist for some types of environmental data that could be very useful to the MEA community. There are well established government archives of space-based EO data of the land, oceans, and atmosphere that are archived on a coordinated basis in the World Data Center (WDC) system established by the International Council for Science (ICSU), and implemented by participating national data centers such as the National Data Centers operated by the National Oceanic and Atmospheric Administration in the United States. The international WDC system is complemented by a range of other national, regional, and mission-specific data centers and archives, such as the European CORINE Landcover data base on environmental characteristics of land-cover based on Landsat and SPOT data, and the Africover data base to be used by the U.N. Food and Agricultural Organization to assist in the fight against desertification. The U.S. National Satellite Land Remote Sensing Data Archive at the EROS Data Center in Sioux Falls, North Dakota, which houses decades of land satellite data, is another excellent resource for the MEA community interested in detecting changes in land cover/land use.

In addition, there are many university data collections and private-sector archives of commercial satellite observations. Despite many significant official and unofficial EO data holdings around the world, there frequently is a lack of commitment on the part of organizations that fund such activities. More specifically, the needs of the MEA community for access to and use of such data holdings have not yet been well articulated to the funders and archivists of EO data and information. It would be especially useful for parties to MEA regimes to define their information and archival needs early in the MEA development process and to communicate those requirements to the EO system operators and the data centers and archives.

Recommendation 5—The operators of EO systems must take actions necessary to ensure the permanent preservation and archiving of data and, in many cases, derived information products to support MEAs, as well as supporting the important objectives of other user groups. At the same time, the MEA community needs to work with the EO community to ensure that relevant archived EO data and information are compatible with and supportive of the special requirements for MEA negotiation and implementation functions.

Finding 6—Cost will be an important concern and constraint in the design and implementation of EO systems and in the production of data and information in support of MEAs. The private sector, including value-added enterprises, could play an important role in the conversion of data gathered by space systems into information useful for MEA implementation and public understanding.

In the design and operation of an experimental/research EO system, the main objective is to demonstrate feasibility and utility of a new type of measurement giving access to a new kind of information; for example, measurement of sea-surface salinity from space could reach an experimental status in the near future. The cost of an experimental project is certainly not irrelevant to the decision-making process as the project must be affordable, but it is not the main driver of the design. In the transition to operational status, since the feasibility and utility elements are already obtained, the pivotal concern becomes achieving maximum cost-effectiveness in the continuous production of reliable information. As an example, in the process deriving the preoperational Jason spacecraft from the experimental TOPEX-Poseidon mission, the mass of the spacecraft has been reduced by a factor of five, resulting in a substantial reduction in cost while preserving the measurement accuracy.

In addition, most EO data acquired from space require considerable processing and interpretation to be useful for specific applications. This analytical and information processing function is commonly referred to as a value-added activity, and in many cases is undertaken by small, highly specialized, for-profit enterprises. The participation of these enterprises is desirable for the production of information useful for the development and implementation of MEAs.

Recommendation 6—Consideration should be given to the most cost-effective means of providing EO data and information products in support of MEAs. Data and information from commercial providers should be considered in addition to utilizing systems operated by governments and multilateral organizations. The opportunities offered by small, dedicated satellites for cost-effective support of specific MEA requirements also should be considered.

Finding 7—Coordination of governmental environmental observing systems and issues by international organizations or forums such as CEOS, IGOS, and WMO consultative meetings is critical for providing support for the development and implementation of MEAs.

The agencies involved in space-based EO activities, as represented in the international Committee on Earth Observation Satellites (CEOS), have begun to engage some of the MEA community through the Integrated Global Observing Strategy (IGOS) Partnership. The IGOS Partnership unites the major space-based and surface-based EO systems for observations of the land, oceans, and atmosphere. It is a strategic planning process that links research, long-term monitoring, and operational programs—as well as data producers and users—in a structure that helps determine observational gaps and that provides a framework for decisions and resource allocations by funding agencies. The IGOS Partnership has already initiated discussions with representatives of 10 major MEA regimes to review possible ways in which IGOS might be able to help support the data and information needs of these MEAs. This positive role of international coordinating bodies for dealing with global environmental observing systems in the MEA context needs to be fully utilized.

Recommendation 7—The EO and MEA communities should vigorously follow up on their initial efforts to improve integration of EO data and information into the MEA process already initiated in forums such as the CEOS and IGOS.

Finding 8—The public has come to rely on and trust some EO data and information products that are presented daily in the media, notably satellite cloud images and weather information. Similar reliance and trust has yet to be established for the broader array of EO data and information products.

Public understanding and support for the use of EO data and information in MEAs is unlikely without public trust and confidence in EO applications that are directly relevant to particular MEAs. But the public in both developed and developing countries needs to gain much greater familiarity with a broad range of EO information products, similar to the familiarity with weather satellite information, before a sufficient level of understanding and trust with these sources will be attained. One way to begin this process is for government agencies providing public benefits related to the environment and natural resource management to enhance understanding through the greater use of EO data and information products. Opportunities for such public uses of EO information are more widely available in the developed world through the public's pervasive access to various information systems such as the Internet, television, and other media. However, developing countries are increasingly gaining such access to these information systems and thus to EO data and information. In India, for example, images derived from land-observing satellites have been presented at township meetings to explain the rationale for planning local infrastructure.

Finally, it should be noted that various nongovernmental organizations (NGOs) have gained an increasing role in bringing environmental issues to the attention of decisionmakers, and especially the public. NGOs now frequently use EO data and information to analyze environmental problems and to publicize them. NGOs also increasingly play the role of unofficial watchdog or enforcer of MEA regimes and in some ways can help promote the interaction between the EO and MEA communities.

Recommendation 8—In cooperation with governments, NGOs, and the private sector, the EO and MEA communities should seek to increase public awareness of the practical benefits of EO data and information products for environmental decision making.

Conclusions

Over 200 MEAs addressing a broad range of environmental issues and concerns have come into existence during the past few decades, but few explicitly incorporate or depend on data and information from space-based EO systems. In particular, EO systems can observe and monitor activities and changes in land, ocean, and atmosphere phenomena such as deforestation, changes in sea level, and the depletion of stratospheric ozone. In many cases, EO data and derived information products can be used to assess the effectiveness of MEAs in achieving their environmental goals and to verify compliance.

The Working Group concluded that EO systems provide relevant data and information that could be used beneficially to a much greater extent in the development and implementation of MEAs. To this end, the Working Group highlighted the desirability of greatly strengthening communications between the EO and MEA communities. The EO community should learn more about the needs of the MEA community, whereas the latter should learn more about EO capabilities to better understand and appreciate what can and—just as important—what cannot be done with EO data and information.